LLANDOVERY AND WENLOCK STRATIGRAPHY OF THE PANUARA AREA, CENTRAL NEW SOUTH WALES

C. J. Jenkins*

[Accepted for publication 20th July, 1977]

Synopsis

Stratigraphy of the Silurian " Panuara Formation " is described from outcrops in its type area, just west of Panuara, near Orange, N.S.W. This " formation " includes three successive phases of deposition, each separated by disconformities—the newly named Cadia and Waugoola Groups and the revised Panuara Group, which now includes the Wallace Shale Formation. Disconformity surfaces are identified lithologically and biostratigraphically. Graptolite assemblages of the *triangulatus, magnus, argenteus, crispus, greistoniensis, crenulata, centrifugus, lundgreni* and *ludensis* Zones are listed. The Ordovician strata immediately underlying contain assemblages of the *linearis, complanatus* and *anceps* Zones. Angullong Tuff volcanism began close to the *linearis-complanatus* zone boundary.

Most lithologies are noticeably diachronous and basal limestones are common above disconformity surfaces. Several new formations and members are described and related to the biostratigraphy.

Introduction

Openly folded and faulted Silurian strata were first noted in the Panuara Area by Booker (1950). In an area which lies 30 km south west of Orange, N.S.W. (Figs 1–2), the Silurian sequence rests disconformably upon andesitic Angullong Tuff (Stevens, 1952) which is high Caradoc to high Ashgill in age. Angularly uncomformable relations exist to the overlying and largely terrestrially deposited Upper Devonian Catombal Group (Connolly, 1963). During Devonian times the Silurian was deformed and deeply eroded so that isolated small outliers of the Upper Devonian are observed resting directly upon lowermost Silurian or even Ordovician beds. A broadly conceived " Panuara Formation " was erected here by Stevens and Packham (1953) to include the entire Llandovery, Wenlock and Lower Ludlow sequence. Several important " unconformities " were recognized however and Sherwin (1971) raised the unit to group status, but without further study of the type area. Sedimentation in the Silurian occurred in three phases, separated by widespread, prolonged disconformities. It is proposed, according to the Australian Code of Stratigraphic Nomenclature, to recognize these as stratigraphic groups. Each consists of distinctive, mappable, areally extensive formations. The " Panuara Group " of Sherwin (1971) is emended here to exclude the earlier Llandovery and Lower Wenlock phases of sedimentation—the Cadia and Waugoola Groups described below (Table 1). These disconformably underlie the thickest and most widespread portion of Silurian sedimentation—the upper Wenlock, Ludlow and Pridoli (emended) Panuara Group. The Wallace Shale, an integral, conformable and lithologically related portion of this phase should be included within the Panuara Group, contrary to the usage in Sherwin (1971).

Since Stevens and Packham (1953), both Stevens (1954) and Warris (1964) have investigated the Angullong Syncline and Packham (1969) has recapitulated (with a few changes) the general geology and graptolite zonation. Sherrard (1954) has described general geology and graptolite zonation. Sherrard (1954) has described several graptolite species and McLean (1974*a* ; 1974*b* ; 1975 ; 1977) most of the rugose corals.

* Department of Geology and Geophysics, University of Sydney, New South Wales, 2006.

Throughout this account the Caradoc-Ashgill boundary is treated as coincident with the *linearis—complanatus* zonal boundary and the base of the middle Llandovery is placed at the base of the *triangulatus* Zone. The succession of facies is described by reference to maps and stratigraphic columns. Graptolite localities are indicated by "g" numbers on either the maps or columns. All specimens of this study are housed in the Department of Geology and Geophysics, University of Sydney.

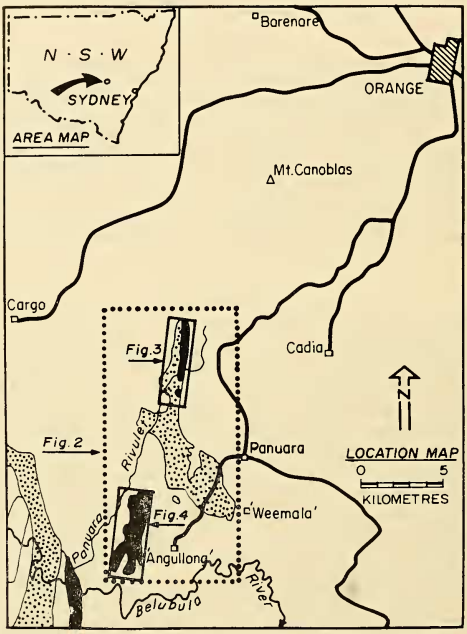

Fig. 1. Map showing location of the Panuara district, and relationship between general and detailed geological maps.

Age of the Underlying Ordovician

The Ordovician basement has been briefly inspected and graptolite horizons collected. Upper Ordovician sediments around Cliefden Caves and Panuara are divided lithologically into the Cliefden Caves Limestone, the Malongulli Formation and the Angullong Tuff (Stevens, 1952). Within the last two units the four uppermost Ordovician graptolite zones of *D. clingani*, *P. linearis*, *D. complanatus* and *D. anceps* are represented.

Moors (1970) described graptolites from the base of the Malongulli Formation, and indentified the *D. hians* Zone of Victoria, equivalent to the British *clingani* zone. An additional collection from the same formation, but at a higher stratal level has revealed the occurrence of the *Pleurograptus linearis* Zone in black siliceous shales, immediately below both a limestone conglomerate and the onset of coarse feldspathic arenites of the Angullong Tuff. This locality, on the north-

Table 1

Relative stratigraphic positions of formal units

Panuara Group
Wallaze Shale
Ulah Formation
" Quarry Creek Hiatus " (Packham, 1969)

Waugoola Group
Glendalcugh Formation
Ashleigh Member
Chaucer Red Bed Member
Burly Jacky Sandstone Member
Cobbler's Creek Limestone
" Panuara Hiatus " (Packham, 1969)

Cadia Group
Cadia Coach Shale
Avon Lea Mudstone Member
Bagdad Formation
Bridge Creek Limestone Member
Wire Gully Limestone Member
" Cobbler's Creek Hiatus " (Packham, 1969)
Underlying Ordovician basement

east flank of Malongulli Hill, was kindly shown to me by Mr. I. Percival (University of Sydney). The locality is shown in Percival (1976 : figs. 2 and 6, section 6). The fauna is : *Climacograptus uncinatus* Keble and Harris ; *C.* aff. *styloideus* Elles and Wood ; *Orthograptus amplexicaulis pauperatus* (Elles and Wood) (see Riva, 1974) ; *O. calcaratus* cf. *basilicus* Elles and Wood ; *Dicellograptus* aff. *pumilis* Lapworth ; *D.* aff. *elegans* (Carruthers); and *Leptograptus flaccidus* (Hall). *C. uncinatus* is an abundant and unmistakable species recorded only from the *linearis* Zone in Victoria (Keble and Harris, 1934 ; Harris and Thomas, 1955) and Nevada, U.S.A. (Carter, 1972) while the remainder of the assemblage is readily comparable to the *linearis* Zone in Britain described by Toghill (1970). An assemblage of *C.* aff. *styloideus* and *O. amplexicaulis pauperatus*, approximately of the same zonal level, has been found at θ1 (Fig. 2) in similar black shales on the north side of the Belubala River. Moors (1970) described *O. calcaratus clavensis* and *Dicellograptus minutus* as new species from the Angullong Tuff. These may represent the *complanatus* Zone, since they lie stratigraphically between the *linearis* and *anceps* Zone faunas of the area.

At a fourth locality (θ2, Fig. 2), just north of Koonoona, Angullong Tuff beds contain a diverse graptolite assemblage of the *anceps* Zone. *Climacograptus supernus* Elles and Wood and *C. latus* Elles and Wood are abundant and together with *Dicellograptus ornatus ornatus* Elles and Wood and *C. normalis* (Lapworth) indicate a fauna of the *anceps* Zone (Toghill, 1970 ; Davies 1929). Additional forms collected include : *Amplexograptus* aff. *prominens* Barrass ; *C. hastatus* cf. *americanus* Ruedemann ; *Orthograptus* sp. nov. ; *O. amplexicaulis socialis* Lapworth ; and *C.* aff. *styloideus*. These horizons lie near the top of the Angullong Tuff but still underlie extrusive andesitic tuffs so that volcanism may have extended just over the Ordovician-Silurian boundary.

These faunal horizons have each been collected within 5 km of Cliefden Caves and indicate that in this area the Malongulli Formation deposition above

the Cliefden Caves Limestone occurred throughout the *clingani* and *linearis* zones. Further east Smith (1966) showed that an easterly facies, lateral to the limestones, ranges down into the Darriwilian. Deposition of Angullong Tuff occurred during the *complanatus* and *anceps* zones.

Cadia Group

At its maximum duration in the Panuara district the *Cadia Group* ranges in age from about the Lower Llandovery *vesiculosus* Zone to the Middle Llandovery *argenteus* Zone (Fig. 3). Succession of facies with the group indicates conditions mostly of transgression for the accumulation of the Bagdad Formation and the Cadia Coach Shale. The former unit consists of limestones and coarse clastics with shelly faunas, while the conformably overlying Cadia Coach Shale is a graptolitic facies (Figs 4, 5 and 6). Formal and informal members are recognized in each. Traces of regressional sandstones appear at the top of the Cadia Group in most sections. The clastic detritus appears to have been derived wholly from erosion of the underlying Angullong Tuff, since the composition of the arenites is overwhelmingly of sodic plagioclase feldspars, pyroxene (largely unaltered) and lithic fragments of a volcanic origin.

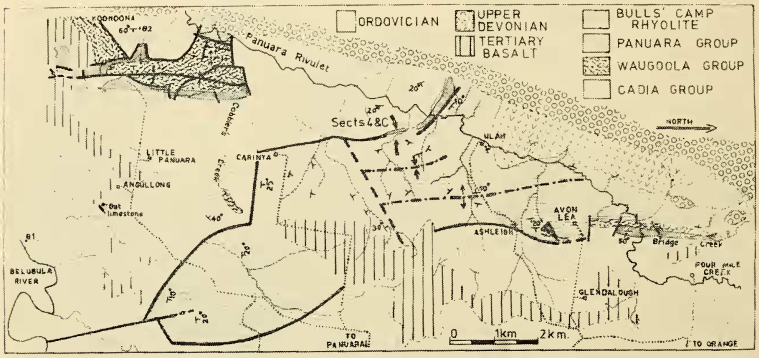

Fig. 2. Map of the general geology of the Panuara district.

Elements of the rugose coral faunas described by McLean (1974*a* ; 1974*b*) were collected from the Bridge Creek Limestone Member of the Bagdad Formation (Table 2). His " Brown Mudstone Horizon " refers to the marly undolomitized development of the member at Trevena's Creek (Fig. 4 and Fig. 6, Section B) while the Bridge Creek locality collections were made from exposures within or close to the type section (Figs 5 and 6, Sections D, E, F). The " Brown Mudstone Horizon " is now considered to be a *cyphus* to *triangulatus* Zone age and the Bridge Creek localities of a *cyphus* Zone age.

Bagdad Formation

The Bagdad Formation varies considerably in thickness and lithological facies over its extent. The type section is 104 m thick at " Trevena's Creek " (Fig. 6, Section B) where there is an almost complete development of its members—the Wire Gully Limestone Member, " Lower Clastic Member ", Bridge Creek Limestone Member and " Upper Clastic Member ", in ascending order. This basic sequence is not so fully developed in sections north of Angullong,

TABLE 2

Rugose and halysitid coral species occurrences in the Bridge Creek Limestone Member

	Locality*			
	1	2	3	4
RUGOSA†				
Streptelasma recisum McLean, 1974*a*			x	
Cystiphyllum kantaikaense (Zaprudskaya, 1962)			x	
Dentilasma rumosum			x	
Dentilasma rumosum McLean 1974*b*,			x	
? *Tryplasma* sp.			x	
? *Tabularia* sp. A			x	
? *Tabularia* sp. B		x		
? *Lambeophyllum* sp.			x	
? *Primitophyllum* sp.			x	
Calostylis panuaraensis McLean, 1974*a*		x		
Grewingkia parva McLean, 1974*a*		x		
G. neumani McLean, 1974*a*		x		
C. siluriense cylindricum Lonsdale, 1839		x		
D. honorabilis Ivanoskiy, 1962		x		
HALYSITIDAE				
Halysites priscus Klaamann, 1966			x	
H. aff. *priscus* Klaamann	x	x		
H. cf. *labyrinthicus* Goldfuss, 1862			x	
Halysites sp. nov.		x		x
H. aff. *amplitubata* Lambe, 1906 (form A)	x			
Catenipora approximata Eichwald, 1829	x			
Eocatenipora sp.				x
H. cf. *priscus* Klaamann			x	

* Localities :

1. Upper half of member at " The Basin ".
2. " Trevena's Creek ".
3. Bridge Creek.
4. South of Ulah homestead.

† Rugose coral occurrences after McLean 1974*a* ; 1974*b*.

but at Ulah an additional unit occurs at the top—the " Haematitic Limestone Member ". All members are diachronous units (Fig. 3), and their individual lithologies vary considerably over the area.

Wire Gully Limestone Member

The Wire Gully Limestone Member is a limestone, ranging from thinly bedded to massive, generally of a reddish colour, apparently because of the incorporation of haematitic silt from the underlying, weathered Angullong Tuff. In the type section (Section B) near " Trevena's Creek " the 35 m thick unit has a sharp upper boundary against olive sandstones and includes a sparse fauna of *Halysites* aff. *priscus* Klaamann, *Palaeofavosites*, *Mesofavosites Heliolites*, a " streptelasmatid " and gastropods. Complex trace-fossil burrows are found elsewhere along this eastern margin of the Angullong Syncline. Basal conglomerates appear and thicken south of the type section.

A distinctly different western facies of this member occurs as the lower of two limestones in the Bagdad Formation at " The Basin " (Figs 4 and 6, Section A). One metre thick beds of grey conglomeratic limestone comprise most of the unit's thickness, but in places, interbeds of calcareous sandstone are important. The unit incorporates basal conglomerates of reworked Angullong Tuff. Rudite lithologies of the limestone contain tuff pebbles also, but they

mostly consist of penecontemporaneously eroded, boulder to sand-sized, limestone detritus. The limestone beds have yielded only one specimen of *Agetolites* aff. *insuetus* Kim, but the uppermost calcareous sandstone beds (below an upward gradation into pure sandstone) contain *Halysites* aff. *priscus*, *Eocatenipora* aff. *vormsiensis* Klaamann and *Hcliolites* spp.

More typical, reddish, massive to crudely bedded limestone of the Wire Gully Limestone Member at Ulah (Fig. 6, Section C) overlies reddish coarse cross-bedded basal sandstones and thick conglomerates of reworked Angullong Tuff. It grades upwards directly into marly Bridge Creek Limestone Member.

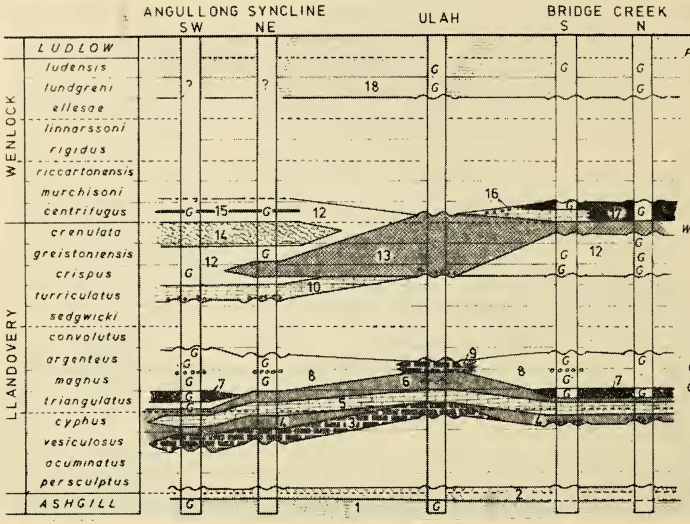

Fig. 3. Biostratigraphic relations of the various facies based mostly upon graptolite occurrences. Zonally diagnostic horizons are marked with a "g". Lithological units are numbered thus : 1. and 2. Angullong Tuff shales and volcanics ; 3. Wire Gully Limestone Member ; 4. "lower clastic member" ; 5. Bridge Creek Limestone Member ; 6. "upper clastic member" ; 7. Avon Lea Mudstone Member ; 8. Cadia Coach Shale Formation ; 9. "haematitic limestone member" ; 10. Cobbler's Creek Limestone Formation ; 11. "*exiguus* beds" ; 12. Glendalough Formation ; 13. Burly Jacky Sandstone Member ; 14. Chaucer Redbed Member ; 15. "black chert horizon" ; 16. and 17. Ashleigh Member limestone and black shale facies ; 18. Ulah Formation.

Fauna is scarce but includes "*Palaeofavosites alveolaris* (Goldfuss)", *Halysites* aff. *priscus* and *Mesofavosites* sp. The member is not developed at all around Bridge Creek, where sedimentation presumably began later.

"Lower Clastic Member"

Sandstones of the "Lower Clastic Member" underlie the Bridge Creek Limestone Member at all localities except Ulah. "Trevena's Creek" exposures are finely bedded, even textured, medium grained, green feldspathic arenites, 33 m thick, unfossiliferous and grading sharply into algal marls of the Bridge Creek Limestone Member. At "The Basin" similar green sandstones contain *Mesofavosites* 3 m from the top. In the vicinity of Bridge Creek (Fig. 6, Section D) what is apparently the same unit lies disconformably, with a basal con-

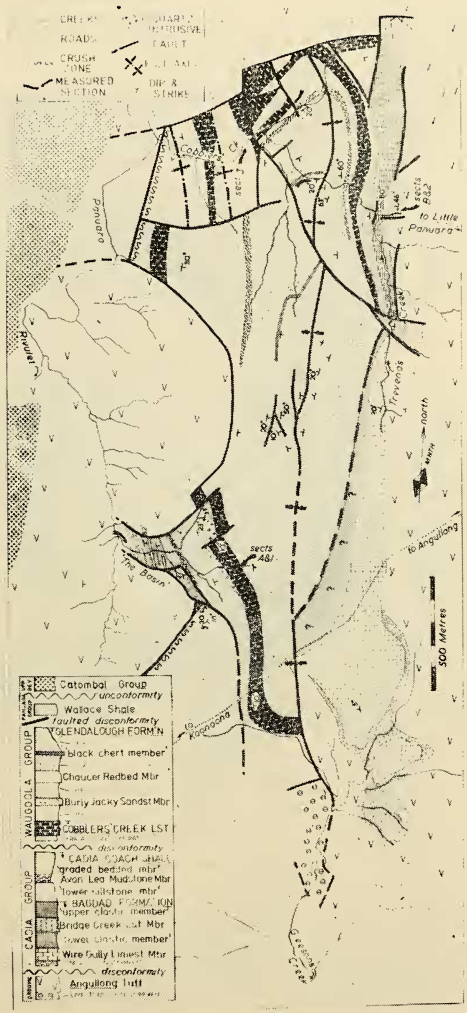

Fig. 4. Map of Silurian geology in the Angullong Syncline, showing some graptolite localities and the measured sections.

glomerate, upon deeply weathered Angullong Tuff. A Silurian age weathering-profile is well exposed at the junction of Wallace and Bridge Creeks. Grits, cross-bedded, coarse feldspathic arenites and finer, thinly bedded sandstones form an upward-fining sequence. The uppermost beds contain limonite nodules, a sparse fauna of crinoid ossicles and immature *Palaeofavosites* colonies in calcareous sandstone.

Bridge Creek Limestone Member

The Bridge Creek Limestone Member (Stevens and Packham, 1953), the only previously formally named within the " Panuara Formation ", has its type section along Four Mile Creek (Figs 5 and 6, Section D). This relatively widespread unit appears 16 m thick here and is everywhere a rhythmically interbedded alternation of calcareous siltstone and algal silty limestones. Individual beds vary in thickness from 2 cm to 10 cm and are traceable over a distance of several metres. The silty limestones are generally rich in disarticulated thallus segments of *Palaeoporella* (see Johnson, *et al.*, 1959). Dolomitization of the member, silicification of fossils and the occurrence of large (50 cm) sized colonies of *H. priscus* and *P. alveolaris* is peculiar to the Avon Lea—Bridge Creek area (Figs 2 and 5).

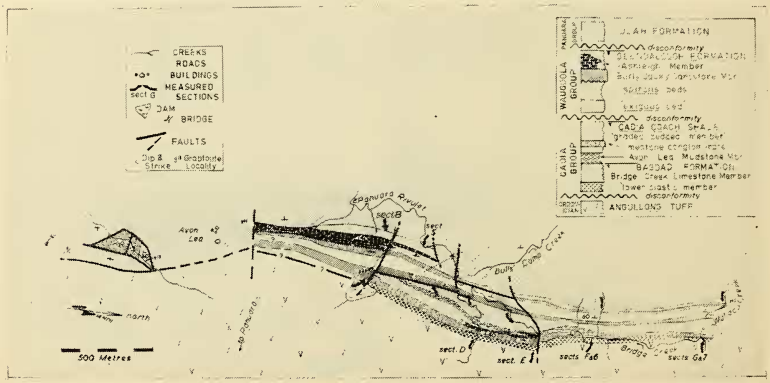

Fig. 5. Map of the Llandovery and Wenlock rocks around Bridge Creek, showing some graptolite localities and the measured sections.

Exposures at Ulah (Figs 2 and 6, Section C) of rhythmically bedded siltstones and marls of this member are sandwiched directly between the Wire Gully Limestone Member and the " Upper Clastic Member ". *Palaeoporella* segments are abundant in the lower beds, but the lithology grades upwards to a poorly bedded calcareous sandstone which is sparsely fossiliferous in eastern outcrops but faunally diverse in the western sections.

Best exposures of the member occur in " Trevena's Creek " (Fig. 6, Section B) however, where all the fossiliferous marly beds amount to about 36 m thickness. Disarticulated palaeoporellid segments are exceedingly abundant, but as at Ulah dolomite and silicification are absent and coral colonies reach only 15 cm diameter. Poorly bedded silty limestone lenses, lacking the siltstone interbeds of the surrounding lithologies, are formed at two horizons in the middle of the member which above becomes slightly more silty and less calcareous.

Correlatives of Bridge Creek Limestone Member at " The Basin " (Fig. 6, Section A) differ lithologically from the eastern facies described above. The member begins sharply as a massive, grey, unfossiliferous and fine grained limestone, which after 17 m thickness is rapidly succeeded by a calcareous and fossiliferous feldspathic sandstone. This encloses several impure limestone lenses of 1–3 m thickness and tens of metres in extent. Corals are plentiful but *Palaeoporella* and rhythmic interbedding of lithologies are absent. Large and often folded intraclasts of laminated calcilutites are common throughout the unit, indicating penecontemporaneous erosion of the member. Graptolite fragments (none identifiable specifically) have been found with ostracods in one fine, tan claystone, within the bedded impure limestone sequence at g0 (Fig. 6, Section A).

The Bridge Creek Limestone is faunally rich at nearly every exposure, the dominant elements being tabulate corals, especially the genera *Palaeofavosites*, *Mesofavosites*, *Favosites*, *Propora*, *Heliolites*, *Halysites* and *Catenipora*. Species of rugose and halysitid corals are listed in Table 2 for various localities. Trilobites are rare, but brachiopods are often common and include two new large species, a *Holorhynchus* and a *Stricklandia*. This latter appears to be characteristic of a lower stratigraphic level than the *Holorhynchus* as a result of either replacement in time or ecological succession of the transgression.

" Upper Clastic Member "

The " Upper Clastic Member " exhibits both a gradational base (from the underlying marls or limestones) and top (mostly into succeeding graptolitic shales). Though mostly a medium-grained feldspathic sandstone in its typical development, the member is often observed with coarser lithologies. In " Trevena's Creek " two very calcareous sandstone and grit lenses are present while at " The Basin ", a conglomerate horizon, only 0·6 m thick, defines the unit's top (Figs 4 and 6). At Ulah the whole member, where exposed, is seen to be a coarse red grit (sometimes calcareous) or even a conglomerate, while at Bridge Creek the unit is wholly a sandstone. Both at Ulah and " Trevena's Creek " beds of transported corals occur near the top of the member.

" Haematitic Limestone Member "

Stratigraphically above the " Upper Clastic Member " at Ulah (Fig. 6, Section C) and not developed elsewhere is the " Haematitic Limestone Member ". Coral fossils *Eocatenipora* sp., *Halysites* sp. nov., *Mesofavosites* and the pentamerid brachiopod *Holorhynchus* sp. nov. are especially abundant near the base of this 7 m thick, silty limestone. The brachiopods occur in a well-bedded horizon only 3 m from the base in outcrops west of the Panuara Rivulet. Above these fossils the red limestone exhibits a vuggy outcrop surface apparently caused by the selective weathering of deep red siltstone intraclasts. At the eastern extremity of the exposures the uppermost beds are almost 60% haematite in composition.

Cadia Coach Shale

Cadia Coach Shale is best exposed at " The Basin ", in the Angullong Syncline and that 105 m thick section is here taken as the type section (Figs 4 and 6, Section A). Many of the species and biostratigraphic events of the classic British graptolite successions (Sudbury, 1958 ; Toghill, 1968 ; Rickards, 1970 ; 1976 ; Burgess *et al.*, 1970 ; Schauer, 1971) may be recognized (Table 4) so that the formations may be divided both lithologically and biostratigraphically. The members apparently have isochronous boundaries. Lithologies of the formation are all feldspathic in composition and differ only in their textures and sedimentary structures. Four members, the " Lower Siltstone Member "

Avon Lea Mudstone Member, " Graded Bedded Member " and an " Upper Sandstone Member " are distinguished, the latter probably being a regressional facies.

" Lower Siltstone Member "

The " Lower Siltstone Member " is a coarse-grained dark grey to green sparsely graptolitic and feldspathic siltstone, succeeding conformably the " Upper Clastic Member " of the Bagdad Formation. At " The Basin " the two differ only in the finer texture and presence of graptolites in the siltstone, but a prominent thin conglomerate bed separates them. Graptolites from the " Lower Siltstone Member " are the ealiest Silurian forms yet known from N.S.W. Two main horizons have been collected in " The Basin " (Fig. 6, Section A). The first (g1) is only 5 m above the topmost conglomerate of the

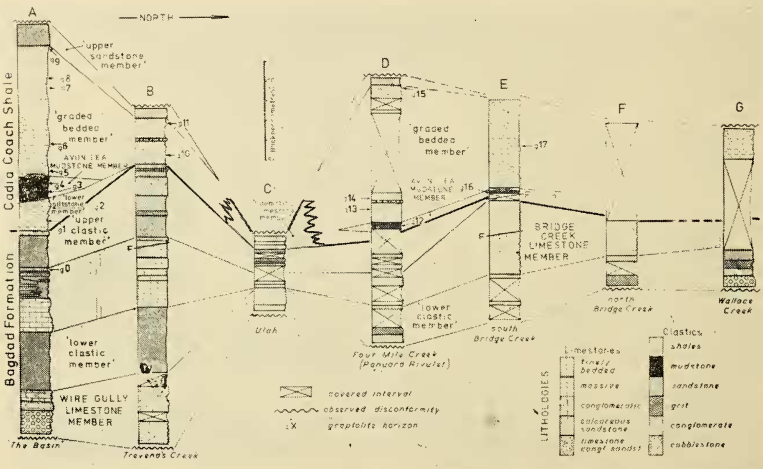

Fig. 6. Stratigraphic sections of the Cadia Group. These measured sections have been located on the maps. Horizontal separations are not to scale.

Bagdad Formation and contains: *Coronograptus gregarius* (Lapworth); *M. triangulatus* aff. *separatus* (Sudbury); and *Monograptus* sp. 1 (with th_{1-2} rastritiform, but distal thecae resembling *M. communis* thecae). *M. triangulatus* aff. *separatus* is also found higher at g2 and both these horizons are correlated with the *triangulatus* Zone, in particular with its lower portion, prior to the appearance of *Rastrites*. The " Lower Siltstone Member " is developed near Gleeson's Creek (Fig. 4) and at " The Basin ", but elsewhere was not deposited.

Avon Lea Mudstone Member

" Lower Siltstone Member " is succeeded by the richly graptolitic Avon Lea Mudstone Member which is easily recognized by its fine texture, lack of well defined bedding and occasional conspicuous white sand-sized feldspar grains scattered through the grey mudstone rock. The mudstone contains graptolites and obolinid brachiopods in profusion at some levels; it is exposed at " The Basin ", Gleeson's Creek, and Bridge Creek with similar faunas and

lithologies developed in each area. The member contains the first appearences of *Rastrites* and *Petalograptus* at approximately the same level. At g3 in " The Basin " are found, *M. triangulatus extremus* (Sudbury) ; *Rastrites* spp.; *Pristiograptus concinnus* (Lapworth) ; *Monograptus* sp.2 (with dorsal curvature, uniformly hooked, low thecae and narrow stipes—see *Monograptus* sp. of Rickards, 1974) ; and *Monograptus* sp.3 (like *M. millepeda* in general shape, but with low, hooked and little-overlapping thecae like *M. communis*). The species *Monograptus* sp.2 is superabundant at some levels in the Avon Lea Mudstone and is apparently restricted to that member, at least in the vicinity of Panuara. Another, slightly younger locality—g4—at " The Basin " contains an assemblage of ; *Petalograptus minor* Elles with *C. gregarius* ; *P.* aff. *concinnus* ; *M. triangulatus separatus; M. triangulatus extremus* ; *Rastrites* spp. ; *Monograptus* sp.2 ; *M.* aff. *revolutus* Kurck ; and *Monograptus* sp.3.

At g12 in Four Mile Creek (Fig. 6), Avon Lea Mudstone exhibits a similar abundance of *Monograptus* sp.2 and *Rastrites* spp. with *M. triangulatus separatus*, *M. triangulatus extremus* and *M.* aff. *revolutus*. Further North, at g16, in Bridge Creek at the crossing of the old coach road to Cadia, *M. triangulatus* aff. *fimbriatus* (Nicholson), *M. triangulatus separatus* and *Monograptus* sp.2 occur in the mudstone directly underlying the " Graded Bedded Member ".

Faunas of the Avon Lea Mudstone include horizons correlative approximately to the upper *triangulatus* Zone (Rickards, 1970), the " *triangulatus* band " (0 horizon or higher) of Sudbury (1958) and horizons 31–29 of Toghill (1968), all of which are marked by the first presence of *Rastrites* and *Petalograptus*.

" Graded Bedded Member "

A gradational lithological change is represented between the mudstone and this overlying member. This informal member comprises a siltstone—arenite facies with graded bedding, the individual cycles being about 5 cm or less in thickness. The bases of the graded beds are not markedly erosional and the coarse fraction of the cycle is usually very thin compared with the subsequent massive or laminated siltstone. No cross-bedding or ripple-bedding has been observed and each cycle is laterally extensive—over 30 m distance in some outcrops. Large calcareous concretions are common in the sequence at Bridge Creek. Mineralogically the arenites consist of plagioclase fragments of microcrystalline feldspathic volcanics and less common augite laths. The feldspars are albite oligoclase, or less commonly microcline in composition, and do not appear to have been much altered (kaolinized) before deposition. Diagenetic products in the sediments are mainly chlorite and calcite, but some silica (and albite ?) is also present cementing and replacing grains. The sediment is texturally poorly sorted and grains lack rounding, so that the source of detritus appears to have been Angullong Tuff local to the Panuara area.

Limestone conglomerate tongues, possibly the result of submarine detritus flows, are present in both the Angullong Syncline and Bridge Creek areas within the " Graded Bedded Member ". At " The Basin " a single lens of pebbly sandstone, 10 m wide and about 2 m thick may be interpreted as having channel form. The pebbles are of sandstone, limestone (with Cadia Group fossils) and Angullong Tuff though the lens is wedged between the top of the Avon Lea Mudstone Member and the " Graded Bedded Member ".

Stratigraphically higher (*magnus* to *argenteus* Zone) limestone conglomerates, thought to be tongues derived from erosion of the Cadia Group at Ulah, outcrop both in " Trevena's Creek " and north of Avon Lea in Four Mile Creek. The former exposure exhibits two 1·2 m thick beds, separated by shales, and composed of cobble to sand sized clasts of reworked feldspathic sandstones, Angullong Tuff and *Palaeoporella* bearing limestones. North of Avon Lea the conglomerate is composed largely of sandstone and limestone pebbles immersed in a sandy

matrix. The bed lenses out to the north but thickens and becomes less rubbly southwards until its truncation by faulting against the Waugoola Group.

Compared with those of the underlying shales graptolite horizons in the " Graded Bedded Member " are more widely separated. The lower portion is poorly exposed in " The Basin " but one fauna (g5—stratigraphically just above the pebbly channel deposit) contains : *M. triangulatus separatus* ; *M. decipiens* Tornquist ; *M. triangulatus extremus* ; *M.* aff. *communis* (Lapworth) ; and *Rastrites*. A similar zonal level in " Trevena's Creek ", (at g9), bears : *P.* aff. *concinnus*; *M. triangulatus separatus*; *M. triangulatus extremus*; *M. leptotheca*; *M. communis* ; and *Diplograptus* aff. *magnus* Lapworth (some species in abundance). Also in the Bridge Creek area, at g13 in the channel of Four Mile Creek, occur : *M. triangulatus* aff. *extremus* (with proximal end hooked, not coiled ; *M. decipiens* ; and *M. communis*. The last two localities underlie limestone-conglomerate tongues but all are considered to represent levels low in the *magnus* Zone, (Rickards, 1970). A single specimen of *M. changyangensis* Sun, 1933, has been found at about this level within " The Basin " (g20).

The *M. argenteus* Zone faunas which follow are characterized by abundant *M. leptotheca* and *P.* aff. *concinnus* at various levels, but a *Monograptus* sp.4 (like *M. argenteus* (Nicholson) but with the long proximal end bent dorsally through 180° and a slow progression to straight distal thecae) is characteristic also. It has been collected from g17 in Bridge Creek, g18 in the faulted inlier south of Avon Lea homestead and from g11 in " Trevena's Creek ", associated at each locality with *M. leptotheca*, *C. gregarius*, *P.* aff. *concinnus*, *Monograptus* sp.4 and numerous diplograptids. Localities g7 and g8 in the northeastern portion of " The Basin " contain the graptolites *C. gregarius*, ?*Monograptus* sp.4, *P.* aff. *concinnus* and *Rastrites*. Fauna in a light grey spicular siltstone at g9 in the northern arm of the " The Basin ", is slightly younger and may indicate a change to the *convolutus* Zone. Here occur *C. gregarius*, *Monograptus* sp. 4 and abundant *M.* aff. *deliculatus*. Each of these localities closely underlies Cobbler's Creek Limestone and the Panuara Hiatus, but a thin, coarsely textured " Upper Sandstone Member " is the final facies above g9. The 11 m thick sandstone may represent a regressional facies since brachiopods occur, and in Four Mile Creek, directly beneath the " *exiguus* beds " a similar coarse facies occurs with mixed shelly graptolite fauna (g15). The forms include *M. communis*, *Rastrites* and *P.* aff. *concinnus* together with " streptelasmatids ", favositids, trilobites and brachiopods. At " Trevena's Creek " the " Upper Sandstone Member " may be present, but merges with coarse sandstones spanning the Panuara Hiatus. Andesitic feldspar laths of these sandstones are pink and clouded, indicating kaolinization and weathering associated with the hiatus.

Waugoola Group

Strata of the Waugoola Group were deposited in the Upper Llandovery and Lower Wenlock, from the *turriculatus* graptolite Zone to the *centrifugus* Zone (Fig. 3), in conditions similar to the Cadia Group. An approximately transgressional sequence is represented with the basal Cobbler's Creek Limestone facies being succeeded by graptolitic facies of the Glendalough Formation (Fig. 7).

Clastic grains of the group's siltstones and sandstones are dominantly feldspathic as in the underlying Cadia Group. Their mineralogy appears to be the result of supply from the Angullong Tuff and Cadia Group. Quartz grains are common however and are usually of a chalcedonic texture. Pyroxene is absent but the common, opaque heavy minerals that do commonly occur may be degradation products.

McLean (1974*a* ; 1975) described Rugosa from two horizons in Cobbler's Creek (Figs 2 and 4), in the area of the Angullong Syncline, informally termed

the " lower limestone horizon " and the " upper limestone horizon ". The lower is equivalent to the Cobbler's Creek Limestone, probably of a *turriculatus* Zone age and the upper bed is referred to in the Burly Jacky Sandstone Member of the Glendalough Formation, and has *crispus—greistoniensis* Zonal age (Fig. 3). Rugose and halysitid coral species collected at various positions in the Waugoola Group are listed in Table 3.

TABLE 3

Rugose and halysitid coral species occurrences in the Waugoola Group

	Locality*				
	1	2	3	4	5
RUGOSA†					
Cystiphyllum siluriense cylindricum Lonsdale, 1839			x	x	
Angullophyllum warrisi McLean, 1974*b*			x		
? *Palaeophyllum* sp.			x		
Ptychophyllum cf. *sibiricum* Ivanovskiy, 1963 ..				x	
Angullophyllum sp.				x	
HALYSITIDAE					
Halysites lithostrotonoides Etheridge, 1904					x
H. aff. *lithostrotonoides* Etheridge				x	
H. cf. *sussmilchi* Etheridge, 1904				x	
H. amplitubata Lambe, 1906		x			
H. aff. *amplitubata* Lambe (densely packed form B)			x		
Acanthohalysites pycnoblastoides Etheridge, 1904 ..			x	x	
A. cf. *pyncoblstoides* Etheridge	x			x	

* Localities and horizons :

1. Cobbler's Creek Limestone near Gleeson's Creek.
2. Cobbler's Creek Limestone at " The Basin ".
3. Cobbler's Creek Limestone at " Trevena's " and Cobbler's Creeks.
4. Burly Jacky Sandstone in Cobbler's Creek.
5. Burly Jacky Sandstone near Bridge Creek.

† Rugose coral occurrences after McLean 1974*a* ; 1974*b*.

Cobbler's Creek Limestone

In its type section (Figs 4 and 7, Section 2) in " Trevena's Creek ", the Cobbler's Creek Limestone (a name first used in Warris, 1964, unpubl.) is 44 m thick (including basal conglomerate), totally exposed, apparently unfaulted and overlies (disconformably) the Cadia Coach Shale. Basal beds are of a variable clastic lithology which areally varies from coarse feldspathic sandstone through conglomerate sandstones to a cobble-grade conglomerate. The feldspar laths and most of the pebbles are derived from Angullong Tuff. In " Trevena's Creek " the basal sandstone has gradational upper and lower boundaries and no distinct erosional surface is present to mark the disconformity. The conglomerates contain reworked Cadia Group fossils (as do the lower limestone conglomerates within the Cadia Coach Shale). The incoming of calcareous arenite beds is gradual and is associated with limestone-conglomerate horizons composed almost entirely of *Palaeoporella*-rich marly pebbles of the Bridge Creek Limestone. Some Wire Gully Limestone pebbles are present also. Excellent exposures of the low clastic beds within Cobbler's Creek Limestone occur in Cobbler's Creek, where they are boulder conglomerates, composed of Angullong Tuff material in their lower levels with the addition of Cadia Group limestone derivatives at higher levels.

In both Cobbler's Creek and " Trevena's Creek " the actual limestone lithology is bedded on a scale of 10 cm, the beds alternating between calcareous feldspathic sandstone and more pure calcarenites or calcirudites. The calcarenites are composed of fragments of sparingly silicified corals, rounded limestone intraclasts and less commonly, andesitic detritus. The pebbles of coarse rudites are usually transported coral colonies and are set in a calcareous sandstone matrix. Both the calcarenites and calcareous sandstones appear initially to have been quite porous and poorly compacted since load casting has caused their warping and small sandstone dykes are abundant. In both creeks exposures of the limestone rapidly grade into a sandstone which is not at all calcareous in composition thus indicating the onset of Glendalough Formation deposition.

Lowest beds above the disconformity at Gleeson's Creek and at " The Basin " are again dominantly conglomeratic sandstones, grading upwards into limestone-conglomerates and an interbedding of calcarenites and calcareous sandstones. At " The Basin " fine grained or calcarenitic 1 m thick beds of pure limestone, often spectacularly rich in *Pentamerus* cf. *oblongus* Sowerby, comprise the upper half of the formation and are rapidly succeeded by non-calcareous basal sandstones and shales (" *exiguus* beds ") of the Glendalough Formation.

On the southern edge of the fault block at " The Basin " is a small outcrop of this unit which has suffered intense deformation and yet bears a profusion of Upper Llandovery corals mixed with pebbles and grit. Similar outcrops of limestone are known from due south of Koonoona (Fig. 2). East of the Angullong Syncline and due north of Angullong homestead is an outlier of dolomitic and silicified limestone, containing *?Palaeophyllum*, a " cystiphyllid " and *Acanthohalysites* cf. *pycnoblastoides* (Etheridge) which is apparently a facies of the Cobbler's Creek Limestone. It rests directly upon Angullong Tuff and was most likely deposited close to the shoreline of that time. Even further east, Smith (1966) discovered limestone lenses near Weemala (Fig. 1) which are now known to contain *Halysites* aff. *amplitubata* Lambe (form B), a species also found in the Cobbler's Creek Limestone, in " Trevena's Creek ".

The Cobbler's Creek Limestone is absent from Ulah and Bridge Creek, where members of the Glendalough Formation rest directly upon Cadia Group strata.

Glendalough Formation

The Glendalough Formation embraces Upper Llandovery to Lower Wenlock graptolitic strata of not only the Panuara district but also further north near Spring and Quarry Creeks (Packham, 1969 : 110). Several non-graptolite members occur within the formation but are laterally variable and diachronously developed (Figs 3 and 7). These include the Ashleigh Member (a limestone and black shale dolomite facies), the Burly Jacky Sandstone Member and the Chaucer Red Bed Member.

Informal subdivisions are based on the graptolites and not lithologies since these vary enormously within the area. Thus *Monograptus exiguus* and *M. spiralis* beds are recognized within the green-grey shale bulk of the formation.

Total thickness of the formation reaches at least 132 m in the Angullong Syncline where it rests conformably upon the Cobbler's Creek Limestone. The thickness varies considerably, however, and around Bridge Creek where it rests disconformably upon Cadia Coach Shale, only 73 m can be measured in the Wallace Creek type section (Fig. 7, Section 7).

Bridge Creek Area

Here the disconformity surface is sharp, due to the lithological contrast between the underlying sandy Cadia Coach Shale and the siliceous, basal "*exiguus*

bed " shales. This particular bed is persistent for 3·5 km to the south, where it is apparently faulted out (Fig. 5). Along its outcrop some lithological changes occur ; for instance in Wallace Creek immediately to the south, the shales are fine textured and siliceous, but on the southern side of Four Mile Creek the " *exiguus* bed " is a sandstone.

Graptolites in the siliceous shales of the " *exiguus* beds " are assigned to the Upper Llandovery *M. crispus* Zone (Table 4) which is represented chiefly by an abundance of *M. exiguus* (Nicholson), a species which is known to range at least down to the *maximus* subzone in Britain (Rickards, 1970), so that by itself that species cannot be used to provide a zonal age. *M. exiguus*, *M. proteus* (Barrande), *M. crispus*, *M.* aff. *acus* Lapworth and *Monograptus* sp.5 (with biform thecae like *M. galaensis* Lapworth but the rhabdosome is ventrally curved) occur at g23 (the locality referred to in Stevens and Packham, 1953). Within Wallace Creek (g30) *M. exiguus* may be collected with *M. proteus*, and at g26 (Section 6), *M. exiguus* occurs in an extensively altered, siliceous siltstone.

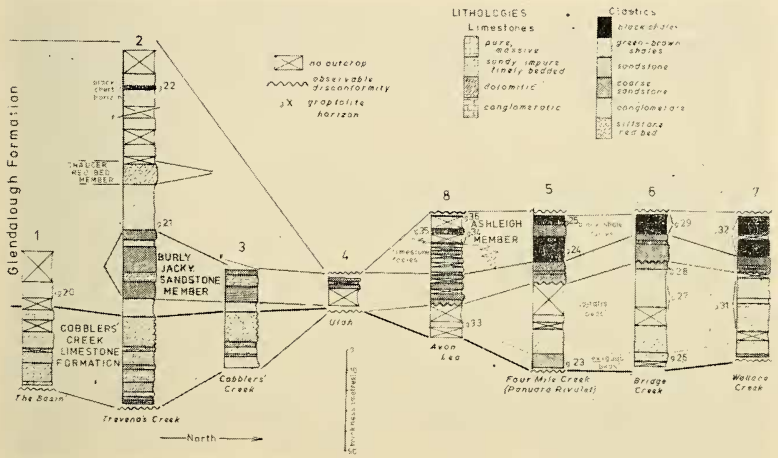

Fig. 7. Stratigraphic sections of the Waugoola Group. The sections are located on map and horizontal distances are not to scale.

In dolomitic siltstones at g33 (near the dam north of Avon Lea homestead and just above the " *exiguus* bed ") is found an assemblage quite different to any *crispus-greistoniensis* Zone faunas in the green siltstone facies : *M. discus* Törnquist ; *M. nodifer* Törnquist ; *M.* aff. *turriculatus* (Barrande) ; *M.* aff. *dextrorsus* Tullberg ; *Stomatograptus* aff. *tornquisti* Tullberg ; *Plegmatograptus obesus* Lapworth ; and *Monograptus* sp.6 (slightly ventrally curved, with all thecae pristiograptid except for a hooked th_1).

Succeeding the " *exiguus* beds " are more finely textured, uniformly olive-green " *spiralis* beds " in which graptolites are abundant. Dendroids and graptolites occur in profusion at all levels and all outcrops around Bridge Creek. The type section is placed in Wallace Creek where (at g31) *M. spiralis* (Geinitz) and *M.* aff. *parapriodon* Boucek occur. Further south in Section G, rare minute

TABLE 4

Zonal occurrences of some graptolite species as observed in the vicinity of Panuara

	Zonal Horizons*											
	1	2	3	4	5	6	7	8	9	10	11	12
Coronograptus gregarius	x	x	x	x	x							
Monograptus sp. 1†	x											
M. triangulatus separatus (Sudbury)	x	x	x									
M. triangulatus extremus (Sudbury)		x	x									
M. triangulatus aff. *fimbriatus* (Nicholson)		x										
M. aff. *revolutus* Kurck		x										
Monograptus sp. 2		x										
Monograptus sp. 3		x										
Pristiograptus aff. *concinnus* (Lapworth)		x	x	x								
Rastrites spp.		x	x	x								
Petalograptus minor Elles		x										
Monograptus communis Lapworth			x	x								
M. triangulatus aff. *extremus* (Sudbury)			x									
M. leptotheca Lapworth			x									
M. decipiens Törnquist			x									
M. changyangensis Sun			x									
Diplograptus aff. *magnus* Lapworth			x									
Monograptus sp. 4				x	x							
M. aff. *deliculatus* Elles and Wood					x							
M. exiguus (Nicholson)						x						
M. proteus (Barrande)						x						
M. crispus Lapworth						x						
M. aff. *acus* Elles and Wood						x						
Monograptus sp. 5						x						
M. discus Törnquist							x					
M. aff. *turriculatus* (Barrande)							x					
M. aff. *dextrorsus* Linnarsson							x					
Monograptus sp. 6							x					
M. nodifer Törnquist							x					
Stomatograptus aff. *tornquisti* Tullberg							x					
Pseudoplegmatograptus obesus (Lapworth)							x					
Monograptus spiralis (Geinitz)								x				
M. aff. *parapriodon* Boucek								x				
M. tullbergi Boucek								x				
M. aff. *greistoniensis* (Nicol)								x				
Stomatograptus grandis Suess									x			
Monograptus priodon (Bronn)									x	x		
Cyrtograptus aff. *centrifugus* Boucek										x		
Monoclimacis vomerina (*s.l.*) (Nicholson)										x		
Monograptus aff. *kolihai* Boucek										x		
M. minimus Boucek and Pribyl										x		
Retiolites obliquidens Obut										x		
Retiolites geinitzianus Barrande										x		
Monograptus testis (Barrande)											x	
M. aff. *flexilis* (Elles)											x	
M. flemingii (Salter)											x	x
Gothograptus nassa (Holm)											x	x
Pristiograptus dubius (Suess)												x
P. ludensis (Murchison)												x
Holoretiolites aff. *lawsoni* Holland, *et al.*												x
Spinograptus cf. *clathrospinosus* Eisenack												x

* Zonal horizons :

1. lower *triangulatus* Zone ;
2. upper *triangulatus* Zone ;
3. *magnus* Zone ;
4. *argenteus* Zone ;
5. *argenteus* to *convolutus* Zone ;
6. *crispus* Zone (" *exiguus* beds ") ;
7. *crispus to greistoniensis* Zones ;
8. *greistoniensis* Zone (" *spiralis* beds ") ;
9. *crenulata* Zone ;
10. *centrifugus* Zone ;
11. *lundgreni* Zone (" *testis* beds ") ;
12. *ludensis* Zone.

† The informally designated *Monograptus* species are referred to in the text.

diplograptids occur with *M.* aff. *greistoniensis* Nicholson at the level of g27. Higher coarse green sandstones directly underlying the Burly Jacky Sandstone Member yield a *crenulata* Zone fauna of *Stomatograptus grandis* Suess and the stratigraphically lowest *M. priodon* (Bronn) (locality g28). Despite an erosional contact between "*spiralis* beds" and the Burly Jacky Sandstone Member no significant time gap exists at the diastem since lowest Wenlock graptolites overlie the sandstone directly.

Burly Jacky Sandstone Member

The Burly Jacky Sandstone Member is a coarse, calcareous, quartzofeldspathic sandstone, developed diachronously in the Cobbler's Creek, Ulah and Bridge Creek areas. The sandstone in its type section in Wallace Creek, (Fig. 7, Section 7) consists dominantly of feldspathic composite-grain clasts and isolated crystals of oligoclase feldspar, both apparently originating from the Angullong Tuff. Quartz grains are also present and are mainly of a chalcedonic structure. Grains similar to vein quartz are also present. Heavy, opaque minerals are especially common, but pyroxene is absent and the sandstone is cemented by diagenetic growths of calcite, chlorite and possibly silica. The unit is often conglomeratic with pebbles of Angullong Tuff, or of rolled coral colonies and displays thick tabular bedding. Most of the coral fauna is indicated in Table 3, but in addition *Multisolenia*, *Mesofavosites* and *Heliolites* are present. In Wallace Creek the sandstone is 11 m thick and is placed near the Llandovery-Wenlock boundary.

Ashleigh Member

The succeeding Ashleigh Member consists of a "limestone facies" and black shale facies which are juxtaposed by an abrupt facies change along its north-south strike. The underlying Burly Jacky Sandstone grades upwards into Ashleigh Member by becoming finer and dolomitized at the top. Facies changes in the Ashleigh Member are apparently due to a northwards slope of the Lower Wenlock topography in the vicinity of Avon Lea and Bridge Creek. Just north of the Avon Lea homestead a bed of dolomitized and silicified fossiliferous Bridge Creek Limestone pebbles (transported from the south near Ulah?) overlies the Burly Jacky Sandstone Member and intertongues into grey micritic and dolomitized Lower Wenlock limestone. Fossils such as *P. alveolaris* and *H. priscus*, typical of the Bridge Creek Limestone Member, are thereby found within Lower Wenlock beds. The Ashleigh Member limestone facies has its own fauna (collected west of the Avon Lea main dam), of *Halysites*, *Mesofavosites* and a "cystiphyllid", most of which have been replaced by dolomite. Just 70 m further north and laterally equivalent the sequence is one of interbedded black or olive black quartzose graptolitic siltstones and silty dolomitic limestone beds comprising about 50% of the total thickness, though further northwards the siltstone proportion grows as the unit thins. One tongue of dolomitic sandstone extends northwards for 300 m from the top of the limestone facies through the graptolitic shales (Fig. 5). Above the limestone facies, which is capped by a thickness of orange dolomitic unfossiliferous limestone beds, are dolomitic black graptolite shales containing at their lowest levels (g34) a retiolitid fauna of *Retiolites geinitzianus* Barrande and *R. obliquidens* Obut. Further up the sequence *Cyrtograptus* aff. *centrifugus* Boucek and *M. priodon* occur with dendroids (g35), while even higher *Monoclimacis vomerina* (Nicholson) (*sensu lato*) occurs at g(36).

In the "black shale facies" north of the limestones an abundant fauna of *Cyrtograptus* aff. *centrifugus*, *M. priodon*, *M. vomerinus* (*s.l.*) and *M.* aff. *kolihai* Boucek has been collected at each of g24, 25, 29, 32, a fauna which in uniform along strike and which may confidently be assigned to the lowest Wenlock, probably the *centrifugus* Zone.

Angullong Syncline

The Glendalough Formation of the Angullong Syncline conformably succeeds the Cobbler's Creek Limestone (Fig, 7, Sections 1–3). Only the basal member (the "*exiguus* bed") is exposed near "The Basin", where 7 m above the limestone a fauna of small diplograptids and *Monograptus exiguus* provides a tentative *crispus* Zone age (g20). Similar sandy quartzofeldspathic tan shales are developed in the syncline's northern sector, but a change of sedimentation environment has occurred over the syncline's length. Beds here are calcareous, sandwiched between two coralline units (Cobbler's Creek Limestone and the Burly Jacky Sandstone) and have a fauna of exclusively dendroid graptolites. The coarse Burly Jacky Sandstone Member here is older than similar lithologies around Bridge Creek and is placed between *crispus* and *greistoniensis* Zone shales. The unit's base is vague, being a gradual coarsening of grain size, culminating with the highly fossiliferous, pebbly and calcareous central portions of the member's 35 m thickness. This fossil band consists of two horizons, the lower spectacularly rich in disarticulated valves of *Pentamerus* aff. *oblongus* and an upper composed of transported corals in pebbly, interbedded limestones and calcareous sandstones. Faunal elements of the band are shown in Table 3. Above this the member grades into shales of the "*spiralis* beds" by interbedding, and only 1 km south of Cobbler's Creek the sandstone apparently lenses out, bringing "*exiguus* beds" and the "*spiralis* beds" into continuity. The succeeding "*spiralis* beds" are graptolitic only at a few thin layers in the black or brown coarse shales near their base; overlying siltstones below the Chaucer Red Bed are olive-grey, bioturbated and barren of remains. The graptolite horizons have yielded (g21, section 2), *M. spiralis*, *M. tullbergi* and *M.* aff. *greistoniensis*, indicating that beneath the red bed the *greistoniensis* Zone is represented.

Chaucer Red Bed Member

The maroon siltstone lithology of the Chaucer Red Bed Member (11 m thick) enters sharply, but upwards becomes increasingly interbedded with green-grey siltstones like those below, so that its upper boundary is vague (Figs 4 and 7). Faulting associated with the axis of the Angullong Syncline also complicates the unit's top in "Trevena's Creek" (type section). Lithologically it is composed of fine quartzofeldspathic silt suspended in a haematitic clay matrix and it appears to be quite unfossiliferous, but since it is found at Liscombe Pools and Millambri it is important as a stratigraphic marker. The member was deposited in marine conditions.

Shales overlying the Chaucer Red Bed Member have a lower Wenlock age and are synchronous with the Burly Jacky Sandstone and Ashleigh Members at Bridge Creek (Fig. 3). Graptolites succeeding the red bed occur in a 30 cm thick "*Black chert horizon*" (Figs 4 and 7) at g22 and include: *M. priodon*; *M. vomerina* (*s.l.*); *M. minimus* Boucek and Pribyl; *Retiolites* aff. *obliquidens*; and ?*Retiolites geinitzianus* Barrande; an assemblage probably indicating the *centrifugus* Zone and which is equivalent to the fauna of the Ashleigh Member further north. At higher levels near the centre of the syncline *M. vomerina* (*s.l.*) has been collected.

Ulah Area

Waugoola Group beds are represented at Ulah by only 15 m of coarse quartzofeldspathic pebbly sandstone (Fig. 7, Section 4) seen there to overlie Cadia Group limestones east of the Panuara Rivulet. The lithology resembles Burly Jacky Sandstone elsewhere and is complete with a coralline band near the top; it includes *Halysites* aff. *sussmilchi* Etheridge, *Favosites*, *Heliolites* and a compound rugosan. It has elements in common with the Ashleigh Member's

Lower Wenlock limestone fauna. The succession at Ulah is conglomeratic and appears to be spectacularly condensed, with Panuara Group shales resting disconformably upon the sandstone immediately above the coralline beds.

Panuara Group

Wenlock age strata occur in the lowest sections only of the Panuara Group, at the base of the Ulah Formation, and it is only these which have been investigated in any detail. Ulah Formation and Wallace Shale comprise the group around Panuara and graptolite zones, from the upper Wenlock *lundgreni* Zone through the Ludlow into the Pridoli, are represented (Fig. 3). In this area the Bull's Camp Rhyolite marks both an end to sedimentation and the top of the group. Detritus is mostly fine-silt sized but coarse quartz-feldspar-biotite arenites, possibly derived from coeval volcanism, are present occasionally.

Ulah Formation

The Ulah Formation is proposed to include about 350 m of quartzofeldspathic shales and occasional arenites below the Wallace Shale (Stevens and Packham, 1953), but overlying, disconformably, sediments of the Waugoola Group. As such it is the thickest single section of the old " Panuara Formation ". Around Bridge Creek (Fig. 5) the basal " *testis* beds " (with *M. testis* (Barrande)) are exposed in the Wallace Creek (g42).

Southwards they become coarser, more siliceous, bioturbated and non-graptolite. No coarse basal lithologies are present, the shale resting directly upon Ashleigh Member, but near Avon Lea the very basal beds are orange coloured because of the incorporation of silt from that member. The basal *lundgreni* Zone beds are also represented at Ulah by the species *M. testis*, *M. flemingii* Salter and *Gothograptus nassa* Holm in olive-green shales.

Overlying strata of the *ludensis* and succeeding (Ludlow) zones are buff coloured, or grey when weathered. Feldspar-quartz-mica arenaceous beds are also present and often very coarse. Just north of Avon Lea homestead (Fig. 5, locality g41) the *ludensis* zone is represented by an assemblage of: *Pristiograptus dubius* (Suess) ; *M. ludensis* (Murchison) ; *Holoretiolites* aff. *lawsoni* Holland *et al.* ; *G. nassa* and *Spinograptus* cf. *clathrospinosus* Eisenack. Near Ulah collections of *M. ludensis* and *M. flemingii* indicate the *ludensis* Zone also. Unfortunately the Ulah Formation is not represented within the Angullong Syncline where the top of the Glendalough Formation has been removed by erosion.

Wallace Shale with its characteristic siltstone-textured interbedded red and green beds succeeds the Ulah Formation, but with no appreciable lithological change from the sediment's quartzofeldspathic composition. The shale is in turn overlain by the Bull's Camp Rhyolite which may have had an extrusive origin and whose age probably ranges into the Devonian (Packham, 1969 : 137).

Structural Geology

The area of Panuara lies on the western flank of the Molong Rise, bordering on the Cowra Trough (Packham, 1960)—a structural downwarp in which Silurian is exposed only in the eastern half. Judging from presently available outcrops, the Molong Rise basement appears to have been composed largely of structurally competent Middle and Upper Ordovician andesitic volcanic piles such as the Walli Andesite and Angullong Tuff (Packham, 1969 : 218). This may explain the largely faulted and openly folded deformation style of these " basement " and younger rocks. Strain developed during the deformation appears to have been released mainly by large scale structures and there has been little or no rock-fabric distortion except within fault zones.

The Angullong Syncline (Figs 2 and 4) extends between Cobbler's Creek and Gleeson's Creek just east of the Panuara Rivulet and west of Angullong. As there is some closure at either end, it is actually basinal in form. The axis is faulted with offset being minimal in the north but increasing southwards so that the south-eastern side is upthrown. Dips at the southern extremity are generally small (20°–30° on either limb) but they increase northwards so the northeastern limb dips steeply at about 60° W while the western limb generally dips at about 30°–40° E. The eastern sequences here often display minor strike-faulting and the western limb is folded. The western and northern margins to the syncline are almost entirely faulted against Angullong Tuff by strike-and-cross-faulting. Only at "The Basin" and along the syncline's eastern margin do Lower Llandovery strata rest disconformably upon the Ordovician. Middle Llandovery shales have been faulted against Ordovician formations in the vicinity of Gleeson's Creek.

Outcrops of the Cadia Groups just south of Ulah rest disconformably upon Angullong Tuff and dip at about 10° northeast. A complete succession (with breaks) from Ordovician through the Cadia and Waugoola Groups to the Panuara Group exists in this belt east of Panuara Rivulet, but westwards the Waugoola Group becomes faulted out.

At Bridge Creek (Figs 2 and 5) the interaction of facies and disconformities with abundant cross-and-strike-faulting has caused interpretation problems. Outcrop in a critical area just north of Avon Lea is poor. The strata dominantly strike north-south and dip at about 50° W. The Mount Canobolas Tertiary Lavas (to the north) and Upper Devonian quartzose sediments (to the west) conceal Silurian under an angular unconformity. Small outlier pods of the Upper Devonian exist further east, one occurring upon the Bridge Creek Limestone and Cadia Coach Shale just east of the Bridge Creek and Four Mile Creek junction. Along its eastern edge the Silurian is bounded by disconformably underlying Angullong Tuff, though a faulted contact exists around Avon Lea homestead and further south. The mapped discordance between Cadia and Waugoola Group strata north of the homestead is probably due to related faulting. A small totally fault-bounded inlier of Cadia group sediments exists just south of Avon Lea and has an easterly faulted contact to vertical Panuara Group shales.

Acknowledgements

The author is especially grateful to Associate Professor B. D. Webby for his guidance and criticism and to Associate Professor G. H. Packham for the loan of graptolite specimens and literature. Dr. R. A. McLean and Dr R. B. Rickards kindly checked the manuscript and Miss P. A. Brown assisted preparation. Professors G. M. Philip (Sydney) and H. B. Whittington (Cambridge) are thanked for university facilities made available.

Financial assistance of the Commonwealth of Australia and ESSO (Australia) is acknowledged.

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